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The Effect of Rotor Tip Markings on Judgements of Rotor Sweep Extent

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Air Operations Division
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ABSTRACT

In this study we investigated the possibility of increasing the visibility of helicopter rotor tips when viewed from the underside. In an experimental study we used a model of a rotor blade spinning at a fast enough rate that it appeared as a transparent disk. The tips of the blades were painted fluorescent red-orange, and were observed under three different lighting conditions. In one condition the tips rotated against a bright background with no additional lighting. In a second condition the tips were lit from the underside by a spotlight to produce the same contrast that would be produced by a searchlight in daytime. In the control condition a darker blue background was used, so that the orange rotor tips were highly visible. Six observers used a computer-controlled pointer that they placed directly under the far edge of the visual disk produced by the spinning rotors. Overall, the results indicated that the ability to judge the distance of a spinning rotor is not strongly affected by lighting conditions. It therefore appears that the problem of judging the distance of rapidly spinning helicopter rotors is unlikely to be solved by enhancing their visibility.

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The Effect of Rotor Tip Markings on Judgements of Rotor Sweep Extent

Executive Summary

In this study we investigated the possibility of increasing the visibility of helicopter rotor tips when viewed by observers from the underside. The effect of rotor visibility on the ability to accurately judge the distance of the tips was the primary variable of interest. Rotor paint schemes have been used to increase the visibility of spinning propellers and tail rotors when aircraft are on the ground. They have also been used to increase the visibility of rotorcraft when viewed from above. However, these paint schemes have not been used on the underside of helicopter main rotors. This is because the rotors are usually viewed in silhouette against a brighter background.

In the laboratory we used a model of a 45 cm diameter rotor blade spinning at a fast enough rate that it appeared as a transparent disk. The tips of the blade were painted fluorescent red-orange. The view of observers was restricted to the region of the tips by means of a head restraint and a viewing aperture. The viewing distance was 2.64 m so that the rotor disk subtended 9.7 deg. Three lighting conditions were used. In one condition the tips rotated against a bright background with no additional lighting. In a second condition the tips were lit from the underside by a spotlight to produce the same contrast that would be produced by a searchlight in daytime. In the control condition, a dimmer blue background was used, so that the orange rotor tips were highly visible. Six observers used a computer-controlled pointer that they placed so that it was apparently directly under the far edge of the visual disk produced by the spinning rotors. Each observer made 30 adjustments under the three lighting conditions.

Daylight photometry showed that even the brightest fluorescent paints would be invisible against the daytime sky without an intense artificial light source such as a searchlight. The experimental results showed bias in observers' distance judgements that was consistent across the three conditions. Within each condition, there was slow drift of increasing error in distance judgement during the 30 trials. This drift was removed by fitting a cubic polynomial function. The residuals from this trend line appeared to be randomly distributed. The variance of these residuals was somewhat less under the condition where the tips were artificially lit from below, but were viewed against a bright background. Overall, the results indicated that the ability to judge the distance of a spinning rotor is not strongly affected by lighting conditions. This is because when viewing a nearly horizontal line through an aperture, there are few cues to depth. In this situation, the accommodative state of the eyes might account for the paradoxical result that under high contrast conditions, performance was not enhanced. It, therefore, appears that the problem of judging the distance of rapidly spinning helicopter rotors is unlikely to be solved by enhancing their visibility.

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1. Introduction

The purpose of the research described in this report was to examine whether rotor tip markings would have any effect on the ability of helicopter pilots to judge the extent of main rotor sweep. Misperception of the distance of the outer edge of helicopter rotor blades may contribute to strikes between rotor blades and nearby objects, with potentially severe consequences. The aim of this project was two-fold. The first aim was to investigate ways of making helicopter rotor tips more visible to the pilot. The second aim was to determine whether increased visibility improves the judgement of the distance of the rotor tips, with a view to minimising the incidence of rotor strikes with obstacles.

1.1 Rotor strike incidents

A rotor strike can be the result of judging the rotor disk to be closer than its actual distance, an object to be more distant than its actual distance, or a combination of these judgement errors. Anecdotally, it is thought that experienced pilots learn the extent of the rotor disk, and that strikes are more likely to be the result of perceiving the distance of obstacles in the environment to be farther than their true distance. This kind of error is likely to occur in conditions where there is an impoverishment of depth cues. For example, when a helicopter hovers in front of a cliff-face, or is descending close to a forest clearing, there are few linear perspective cues, and the main cue to distance is the texture of the potential obstacle. If the texture of rocks or vegetation is finer than that usually encountered, the pilot may assume that the surface of the obstacle is further away than it really is, increasing the chances of a rotor strike.

However, some incidents have been attributed anecdotally to difficulties seeing the edge of the transparent disk formed by the spinning rotors, or to the difficulty of estimating the distance of a faint, nearly horizontal edge. Because our eyes are separated horizontally, the visual system requires vertical or oblique contours in the visual scene for an observer to make use of the binocular distance cue of retinal disparity, or stereopsis, for distance judgements. Accurate distance estimation is required in these situations where both visual contrast and cues to stereopsis are impoverished. The question addressed in this study is whether an improvement in the visual contrast of the rotor tips can be achieved, and if so, will it improve the accuracy of distance estimation?

1.2 Rotor visibility

Research into the visibility of rotors has been carried out in two contexts. There has been interest in the problem of persons being stuck by the propellers of aeroplanes or the tail rotors of helicopters while boarding or disembarking (Collins et al., 1981; Collins, 1993). There has also been research into the problem of helicopters colliding with other helicopters while landing, due to the pilots' difficulty in seeing rotorcraft below them, especially in dusty conditions (Bynum *et al.*, 1967; Crosley, Bailey & Nix, 1967). We have, however, not found any published research into the visibility of main rotors from the pilot's point of view, for reasons that will become apparent below.

There are no compulsory standards relating to the visibility of propellers or tail rotors. Paint schemes used to make these more visible, especially when rotating, reflect only the choice of the aircraft manufacturer. There is a long history of research into this issue. Lazo (1954) found that a colour scheme incorporating black, white and red located concentrically on the propellers of fixed wing aircraft to be superior to other schemes tested. Further investigations were carried out by Crosley *et al.* (1972), who considered the following factors in relation to the visibility and conspicuity of different paint schemes:

1. Colour contrast with the background
2. Colour contrast within the paint scheme
3. Brightness contrast with the background
4. Brightness contrast within the paint scheme
5. The ability of the paint scheme to generate the visual sensation of flicker
6. The interaction of the above factors with rotational speed
7. The retinal angle subtended by the propeller or rotor

The visibility of numerous colour schemes was tested, both with large blades (propellers) and small blades (tail rotors). Based on the conspicuity ratings of observers, made against different backgrounds (treeline, open field, other aircraft / buildings), the researchers recommended the colour scheme illustrated in Figure 1.

Figure 1: The colour scheme recommended by Crosley et al. (1972) to maximise the conspicuity of propellers and tail rotors

This scheme comprises fluorescent red-orange tips, combined with alternating black and white segments on opposing blades, to create perceptual flicker at low rotational speeds. It was subsequently found, however, that the fluorescent paint tended to become viscous and "gummy" at high speeds, and faded rapidly with exposure to UV light. Crosley *et al.* (1972) therefore recommended the second-best scheme, using high-gloss yellow in place of red-orange fluorescent paint. Unfortunately, they did not try a gloss red-orange paint within the study. Modern fluorescent paints are UV-resistant and have improved mechanical stability. They are not in widespread use, probably because of higher maintenance costs. Nonetheless, for experimental purposes we have persisted with the most conspicuous colour (fluorescent red-orange) in the present study.

2. Method

2.1 Photometry for the rotor blade experiment

In the present study, we tested whether the main rotors of helicopters can be made more conspicuous from the point of view of the pilot. In this situation, under daylight viewing conditions, the rotor blades appear as a faint dark transparent disk against the background. Coloured paints also appear dark due to a “silhouetting” effect. In order to make the situation more comparable to the case of propellers, tail rotors, or main rotors viewed from above, it would be necessary to have an external light source illuminate the underside of the blade. It may be possible to modify a searchlight to illuminate the underside of the main rotor blades in daylight, in combination with a conspicuous paint scheme applied to the underneath surface of the blades. To test these possibilities, we needed to measure representative luminance in an outside environment so that equivalent contrast relationships could be tested in the laboratory, albeit at lower absolute luminance levels. The level of daylight illumination using searchlights was also estimated.

It was estimated that a helicopter spotlight can illuminate the ground to a level of 32 lux at a distance of 1,000 m. Using the inverse square law, this corresponds to 5700 lux at 7.5 m, the approximate distance of the blade tip from the pilot in a medium-weight helicopter. The measured reflectivity (including fluorescence) of orange-red fluorescent paint is approximately 60%. To convert iluminance and reflectance to surface luminance we used the following:

5700 lux x 60% reflectance = 3420 lm / m^2
and 3420 / π = 1088 cd / m^2

The luminance of the daytime sky can be up to 4000 cd / m^2, so the best luminance contrast that can be achieved for the underside of blades against the sky is in a ratio of approximately 1:4.

2.2 Luminance contrast under daylight conditions

To confirm the above values, we carried out photometry in the outside environment during the middle of the day. The grounds of DSTO contain several aircraft, surrounded by a mixture of grass, concrete and asphalt and we used an aircraft wing as a representative helicopter rotor blade in order to assess luminance contrast from light reflected from the ground onto the underside of a horizontal surface. A card painted with fluorescent orange-red paint was mounted on the underside of the aircraft wing 1.8 m above the ground. Illuminance and reflected luminance were measured using a Pritchard Spectrophotometer. The illumination produced by the sky on this day on the horizontal plane was 2.89 x 10^4 lux. The illuminance reflected from the ground to the underside of the wing was 1.1 x 10^3 lux. The direct measurements of surface luminance, obtained with 1/8 deg and 3 deg fields of view of the spectrophotometer are given in Table 1.

Table 1: Surface luminance

Aperture (deg)	Surface	Luminance (cd/m^2)
1/8	Red-orange paint viewed at angle	2.88 x 10^2
	Red-orange painted view from below	2.68 x 10^2
	Background sky	1.78 x 10^4
3	Red-orange paint viewed at angle	2.25 x 10^2
	Red-orange painted view from below	2.88 x 10^2
	Background sky	1.60 x 10^2

There is some variance in these measures that is probably due to the variability of the sky illumination from changing cloud conditions during the course of taking measurements. It is apparent that the red-orange paint is a good diffuse reflector, because there is little change in the reflected luminance with viewing angle. It is also clear that a limited amount of reflected light is available to illuminate the paint on the underside of the wing. Thus, the painted surface was silhouetted against the bright sky, making the colour difficult to see.

2.3 Measured luminance in the laboratory

Although it was not possible to replicate the daytime sky luminance in the laboratory, it is important for this study to replicate the same approximate luminance ratios and ensure that both luminances are in the photopic range so that colours can be easily seen.

Using a small spotlight, we illuminated the underside of a model rotor blade which had its tips painted in orange-red fluorescent paint so that the reflected luminance was 110 cd / m^2. The background luminance created by a projector and a spotlight was 551 cd / m^2 which is in the correct range for the equivalent daylight / searchlight combination. This ensured that the luminance contrasts were comparable to the measurements observed using daylight photometry.

When the blade rotated at a fast enough rate for it to appear as a transparent disc, the apparent background luminance of 551 cd / m^2 was reduced to 505 cd / m^2. This relatively low contrast of 4.3% (Michelson) is similar to that of a helicopter rotor blade seen against the sky. If average threshold contrast is approximately 1%, then it is apparent that the edge of a helicopter's rotor disk is difficult to see. Indeed, if colour is added to the tips, that colour is also not visible because addition of colour is likely to reduce luminance contrast. The colour contrast can be increased by illuminating the underside of the blade to increase the amount of coloured light reflected from the tip of the blade, but at the expense of reducing luminance contrast even further to 1.8%. The luminance of the illuminated red orange blade was such that the background viewed through the spinning blade had a luminance of 535 cd / m^2.

2.4 Apparatus

The apparatus is shown in Figure 2 and consisted of a long metal track on which was mounted a computer-controlled pointer that could be moved backwards and forwards by either the observer or experimenter using a joystick. Electronic sensors along the track allowed the computer to accurately determine the position of the pointer, and this was displayed to the experimenter. Above the track was a model 45 cm diameter four-blade rotor angled towards the viewer so that the drive-motor could be masked from view. A viewing aperture was used so that the observer saw only the rotor blade and the tip of the pointer underneath, as shown in Figure 3. A hemispherical and conformal head restraint and chinrest, which together precluded any head movements, were used to maintain the viewing distance of 2.64 m from the far edge of the spinning rotor so that the disk subtended approximately 9.7 deg, and also to prevent the observer from looking under the aperture.

Figure 2: Experimental apparatus. See text for description

2.5 Procedure

After screening for visual abilities (see below) the observers were seated and they placed their head in the headrest. They were familiarised with the use of the joystick to move the computer-controlled pointer. The experimenter then moved the pointer well away from the point directly underneath the rotor blade. The observers were instructed to place the pointer directly under the far edge of the rotor blade by first moving the pointer to the other side of the edge at least once, rather than stopping as soon as they could not perceive any difference in depth between the rotor blade and the pointer. This was done to minimise starting point effects. For each condition, the observers made 30 consecutive adjustments, from starting points strictly alternating between in front of, and behind, the desired location. This represented the minimum number of observations required to estimate the variability of responses under each viewing condition.

2.6 Design

The experimental design consisted of three experimental conditions. In the control condition, the background was blue, and the rotor was illuminated from below to make the red-orange paint on the tips visible (see detailed description of luminance above). This condition is referred to as the “Blue” condition, and is illustrated in Figure 4. Note that this degree of contrast could not be achieved under daylight conditions. It was included to determine if the high contrast would lead to improved depth perception. In the other two conditions the rotor was presented against a bright white background without benefit of additional illumination (“Light-Off” condition), or with the extra lighting (”Light-On” condition) directed at the rotor blades. The “Blue”, “On” and “Off’ conditions were presented in a counterbalanced order.

Figure 3: The pointer and spinning rotor blade as viewed by the observer. The rotor blade is the faint disk at the top of the figure. Under full white background luminance, the transparent disk could not be seen on a photograph, but was visible to the observers. With additional illumination the coloured markings could be seen faintly. (The disc is best viewed on a display monitor using the electronic version of this report. The background in this photograph has been adjusted in order to enhance the disk for illustrative purposes.)

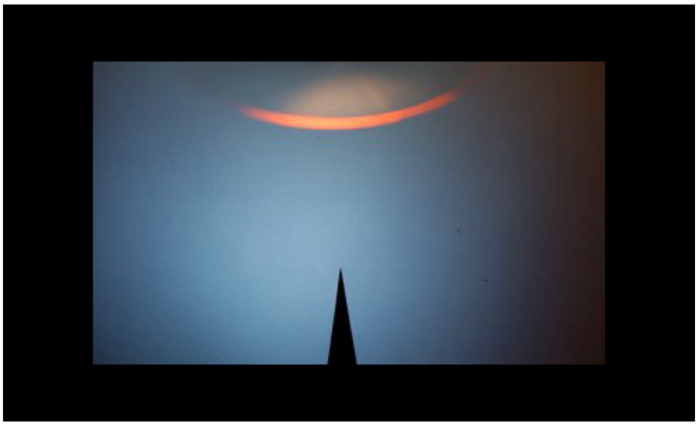

Figure 4: The same rotor blade illuminated from below to reveal the red-orange markings. This degree of contrast cannot be achieved under daylight conditions, but was included as a control condition.

2.7 Observers

Five male and one female volunteers aged between 22 and 36, were used as observers in the experiment. All were screened for normal visual acuity with a Snellen chart, for colour vision using the Ishihara plates, and for stereovision using the TNO stereo test. All participants were DSTO scientific and technical staff, and none were rotary wing aircrew.

3. Results

Figure 5 and Figure 6 show the distance settings made by each observer as a function of successive trials. The left hand panels show the raw results for the each observer. Two features are readily apparent. First, there are individual biases in the average settings made by each observer. Second, in many cases this bias showed a slowly varying drift across the 30 trials. In several cases, polynomial regression showed significant departures from stationarity.

In order to remove the drift, cubic polynomial functions were fitted to each set of thirty trials, and the data are replotted as residuals from these lines in the right hand panels. The mean standard deviations from all participants and for the three experimental conditions are shown in Table 2.

Table 2: Standard deviation of residuals from fitted polynomial regressions of adjustment settings

Condition	Standard Deviation of Residuals	
	Mean (mm)	Standard Error (mm)
"Blue" residual	39.66	5.01
"On" residual	31.82	3.32
"Off" residual	38.39	3.96
"Blue" unadjusted	44.78	4.80
"On" unadjusted	38.42	3.87
"Off" unadjusted	51.53	8.82

The residual values are of primary interest, and the condition where the light was "On", but was presented against a bright white background, yielded a smaller standard deviation than the other two conditions. As can be seen in Table 3, this standard deviation was significantly smaller than when the light was "Off". The "Blue" control condition provided a slightly larger average standard deviation than the "Off" condition, but failed to reach significance when compared to the "On" condition, due to its larger standard error. These results were not as predicted, and their practical implications are discussed below.

Table 3: Numerical difference in mean residuals and results of t-tests

Comparison	Difference	*t*	*df*	*p*
"Blue" residual vs. "On" residual	7.8400	2.505	5	.054
"On" residual vs . "Off" residual	-6.5700	-5.290	5	.003
"Blue" residual vs. "Off" residual	1.2700	0.462	5	.664
"Blue" unadjusted vs "On" unadjusted	6.3583	4.321	5	.008
"On" unadjusted vs "Off" unadjusted	-12.9083	-1.755	5	.140
"Blue" unadjusted vs "Off" unadjusted	-6.5500	-1.073	5	.332

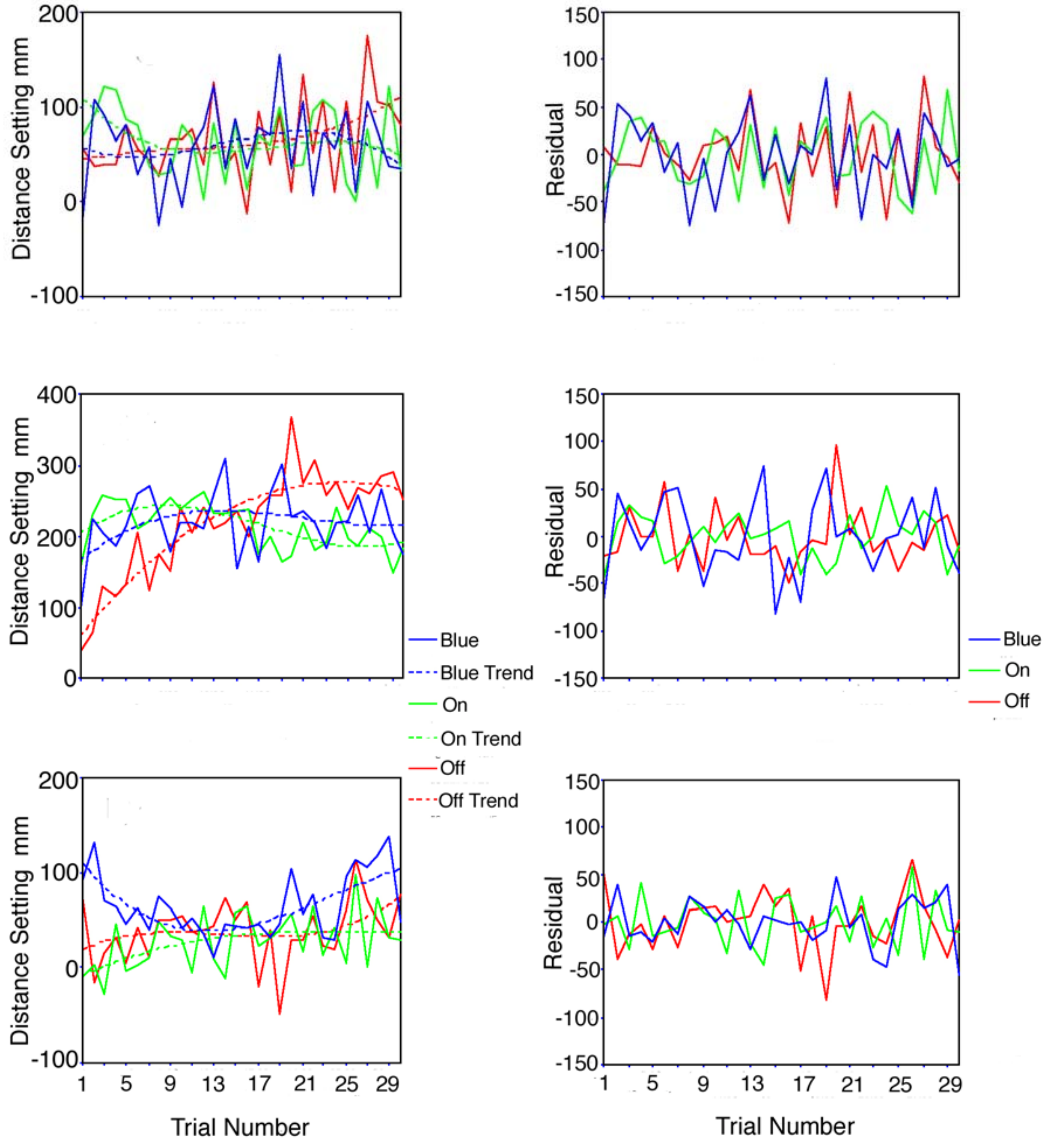

Figure 5: Results for the first three observers (top, middle, and bottom rows) under the three viewing conditions. The left panels show the raw distance settings and cubic polynomial trends. The right hand panels show residuals from the polynomial trend lines.

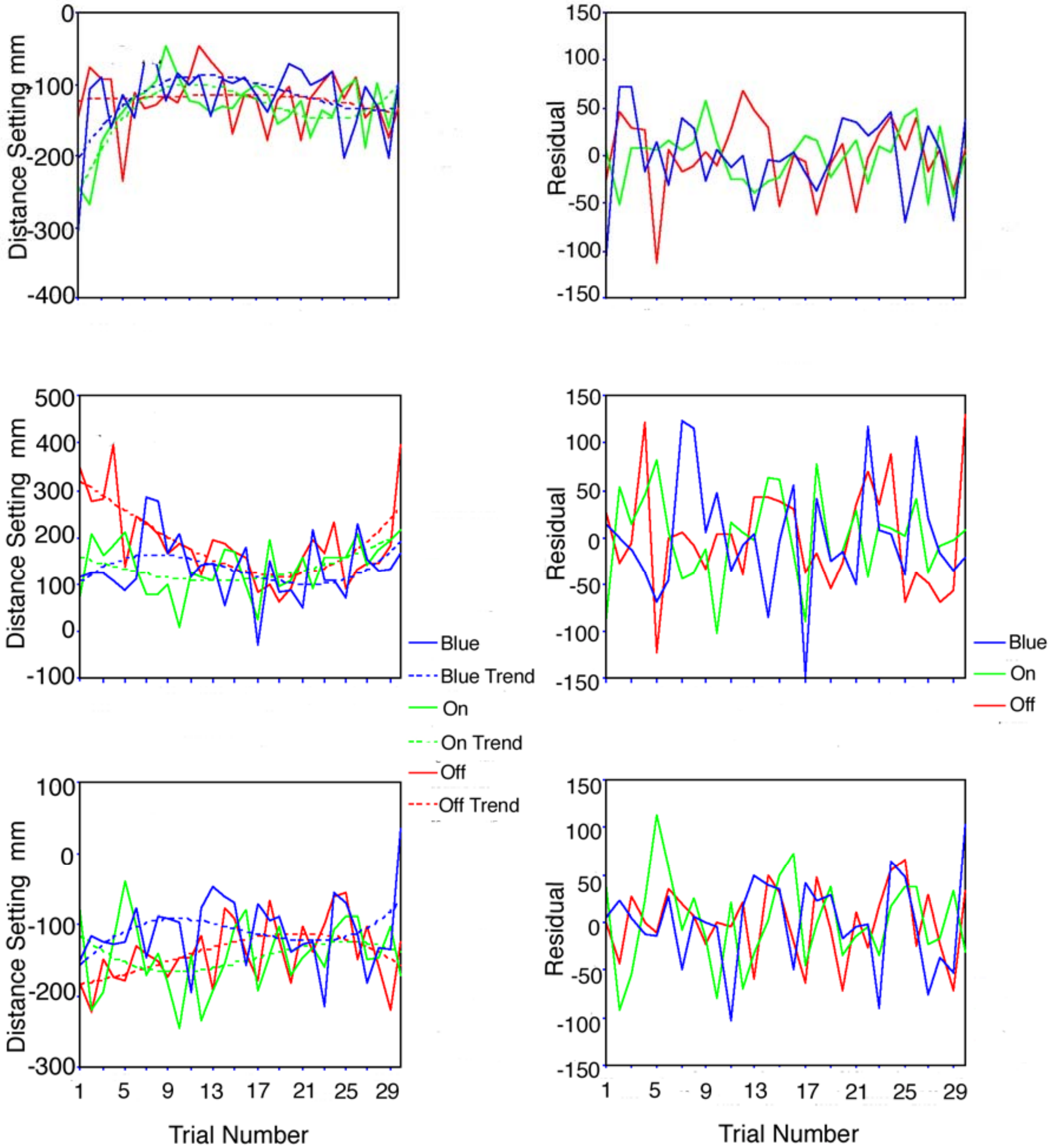

Figure 6: Results for the remaining three observers (top, middle, and bottom rows) under the three viewing conditions. The left panels show the raw distance settings and cubic polynomial trends. The right hand panels show residuals from the polynomial trend lines.

4. Discussion

The results demonstrated, somewhat contrary to expectation, that participants' ability to accurately and consistently judge the distance of the tips of a model rotor blade did not depend on the degree of visual contrast of the rotor tips with the background. In fact, the condition with the highest contrast i.e. "Blue", which was included as a control condition, resulted in the most degraded performance. The slight reduction in the variance of distance settings using artificial illumination must be considered in the context of the high degree of individual variation and the drift in settings within the blocks of trials. This means that any technical intervention to provide illumination of painted rotor tips from below is unlikely to overcome the impoverishment of visual depth cues that makes this judgement so difficult.

Most binocular and monocular cues to distance are absent in the experimental setup used in this study. This parallels the real situation of a pilot viewing the rotor blades from within a helicopter. Importantly, the transparent arc formed by the spinning rotors is virtually a horizontal line, especially just above the pointer where the observer was required to judge distance. In a helicopter, the rotor traces out an even wider arc. This rules out the use of both binocular stereopsis and vergence as cues to depth. The distance of objects lying on the ground can be judged using monocular distance cues such as linear perspective, texture gradients and visual elevation. Some use of elevation angle might be used to judge the distance of the rotor tips of a real helicopter as these are known to be roughly horizontal. In this experiment, however, the model rotor had to be tilted to remove the centre of the rotor from the field of view, also ruling out this cue. Perhaps the remaining cue to distance is the accommodative state of the eyes when focussing on the rotor tips.

A visual accommodation cue is known to be a relatively poor cue to distance. For example, Takeda *et al.* (1999) found that other cues to apparent depth drove accommodation, rather than the reverse. That is, the eyes tend to initially focus to the perceived distance of an object. In a recent study, Mon-Williams & Tresilian (2000) found that accommodation was a very poor absolute distance cue. When it was the sole cue available, they reported that "observers were extremely poor at carrying out the task when accommodation was the only distance cue available. Responses on individual trials bore little relationship to the actual target distance in any of the observers" (p391). Accommodation appeared to provide a weak cue to ordinal distance of targets on successive trials. Thus, accommodation may be of some use when two objects are in view, as in the present experiment. Nonetheless, the bias and drift observed in the experiment is consistent with the findings of Mon-Williams & Tresilian (2000).

The variable performance exhibited by our participants and the result that the highest contrast stimulus condition resulted in the poorest performance suggests that the depth alignment task was difficult to perform. We conclude that the lack of salient depth cues available to participants made this a very difficult task. Although motion parallax is a monocular cue that is usually available to make depth judgements, it was unavailable to our participants because their head was restrained. We also conclude there were no binocular cues available because the horizontal appearance of the spinning disk did not provide any compelling horizontal disparity cues. Although we did not measure or control for the accommodative status of observers, this cue is unlikely to provide accurate depth judgements (Mon-Williams & Tresilian, 2000), and in any case the high contrast "Blue" condition resulted in relatively poor performance. There are therefore few opportunities to ameliorate the relative difficulty of this alignment task in such an impoverished visual environment.

5. Acknowledgement

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6. References

Bynum, J. A., Bailey, R. W., Crosley J. K. & Nix, M.S. (1967). Development of a paint scheme for increasing helicopter conspicuity. (USAARL Report No. 68-1). Fort Rucker, Alabama: U.S. Army Aeromedical Research Laboratory.

Collins, W.E., Mastrullo, A. R., Kirkham, W. R., Taylor, D. K., & Grape, P. M. (1993). An analysis of civil aviation propellor-to-person accidents: 1965-1979. (Report No. AM-81-15). Oklahoma City, Oklohoma: FAA Civil Aeromedical Institute.

Collins, W. E. (1993). A review of civil aviation propellor-to-person accidents: 1980-1989. (Report No. DOT / FAA / AM-93 / 2). Oklahoma City, Oklohoma: FAA Civil Aeromedical Institute.

Crosley, J. K., Bailey, R. W., & Nix, M.S. (1968). Improving helicopter conspicuity through the use of painted main rotor blades. (USAARU Report No. 68-2). Fort Rucker, Alabama: U.S. Army Aeromedical Research Unit.

Crosley, J. K., Tabak, R. G., Braun, E. G., & Bailey, R. W. (1972). Improving U.S. Army aircraft propellor and tail rotor blade conspicuity with paint. (USAARL Report No. 72-15). Fort Rucker, Alabama: U.S.Army Aeromedical Research Laboratory.

Lazo, J. (1954). Investigation of colour schemes to improve propellor noticeability. (Report XG-T-213). Philadelphia: Naval Air Materiel Center.

Mon-Williams, M., & Tresilian, J. R. (2000). Ordinal depth information from accommodation? *Ergonomics, 43,* 391-404.

Takeda T., Hashimoto K., Hiruma N. & Fukui Y. (1999). Characteristics of accommodation toward apparent depth. *Vision Research, 39,* 2087-2097.

Welsh, K. W., Vaughan, J. A., & Rasmussen, P. G. (1978). Conspicuity assessment of selected propellor and tail rotor paint schemes. (Report No. FAA-AM-78-29). Oklahoma City, Oklohoma: FAA Civil Aeromedical Institute.

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19. ABSTRACT
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